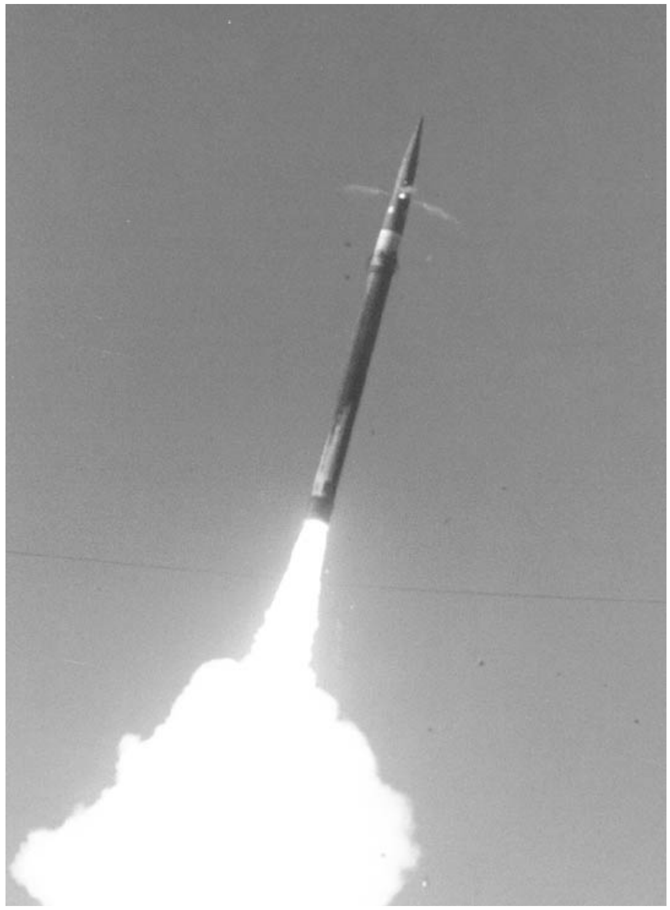
THEATER HIGH ALTITUDE AREA DEFENSE (THAAD)



Army ACAT ID Program		**Prime Contractor**
Total Number of Missiles:	1250	Lockheed Martin Missiles and Space
Total Program Cost (TY$):	$23,000M (w/O&S costs)	Sunnyvale, CA
Average Unit Cost (TY$):	BY00--$1.8M	
	BY88--$1.3M	
Full-rate production:	FY08 (Configuration 1)	

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2020

The Theater High Altitude Area Defense (THAAD) is a mobile ground-based Theater Missile Defense (TMD) system designed to protect forward-deployed military forces, population centers, and civilian assets from Theater Ballistic Missile (TBM) attacks. THAAD negates incoming ballistic missiles utilizing hit-to-kill technology (i.e., kinetic energy) and is capable of intercepting them at either endoatmospheric or exoatmospheric altitudes. As a core element of the Family of Systems layered defense architecture, it provides upper-tier missile defense in concert with the lower-tier systems, PATRIOT Advanced Capability-3 (PAC-3) and Navy Area TMD.

The THAAD system is comprised of the following segments: mobile launchers, interceptors, radars, Battle Management/Command, Control, Communications, and Intelligence (BM/C^3I) units, and ground support equipment. The launcher system is a modified U.S. Army palletized loading system truck, equipped with a missile-round pallet, launcher, electronic controls and communications. The interceptor consists of a single-stage, solid-fuel booster—which employs thrust vector control technology for boost phase steering—and a separating kill vehicle that uses an infrared seeker and divert thrusters for terminal guidance and control. The THAAD radar is a solid-state, X-band, phased-array antenna that performs search, track, threat type classification, and interceptor fire control functions. As the communications link between the BMC^{3}I and interceptors, the THAAD radar also delivers target updates to the kill vehicle, which are used for mid-course guidance. The THAAD BM/C^{3}I segment manages and integrates all THAAD components to control the THAAD weapon system. Its major components are the Tactical Operations Station, the Launch Control Station, and the System Support Group. These components can be configured to form a Tactical Station Group, Tactical Operations Center, Sensor System Interface, or a Communications Relay. The Tactical Operations Station and the Launch Control Station are transported on High Mobility Multi-Purpose Wheeled Vehicles; the System Support Group carrier is a production standard 5-ton cargo truck.

THAAD embodies ***Joint Vision 2020's*** operational concepts of ***dominant maneuver***, ***precision engagement***, and ***full-dimensional protection***: THAAD is a mobile, integrated system of elements that provides responsive command and control to locate and engage attacking TBMs. ***Information superiority*** enables THAAD to operate within a communications network, receiving and exchanging data with external sensors, PAC-3, Navy Area, and other theater air and missile defense systems. Furthermore, THAAD is designed to rapidly respond to military crises and, therefore, incorporates the fourth operational concept of ***focused logistics***.

BACKGROUND INFORMATION

The Gulf War demonstrated an immediate need for an effective and dedicated missile defense system capable of countering TBM attacks. Congress recognized this need in the National Missile Defense Act of 1991 and the Defense Appropriations Act of 1991, which established the requirement for a "deployable TMD demonstration system" for forward-deployed U.S. and Allied Forces by the mid 1990s. A mature system with full capabilities was to be developed by the year 2000.

The long-term response to this requirement is the development and eventual deployment of the THAAD "objective" system. The THAAD User Operational Evaluation System (UOES), now terminated, would have been the demonstration system using prototype equipment to perform early operational assessments and deploy in the event of a "national emergency" contingency operation.

Currently, THAAD is planning to meet its ORD requirements through two sequenced configurations, both developed during EMD, employing an "Evolutionary Acquisition" approach. The Configuration 1 system provides a significant warfighting capability while deferring some software (time-intensive) development for the BMC^{3}I and Radar to Configuration 2. Configuration 1 is intended to meet the seven key performance parameters of threat, range and radar cross-section, defended area, protection effectiveness, lethality, kill probability, and interoperability. The missile design will be matured for Configuration 1. The Configuration 2 system delivers full ORD compliance. Currently, Configuration 1 will enter production in FY09. Configuration 2 upgrades will be available in FY12.

THAAD entered Engineering and Manufacturing Development (EMD) in June 2000. THAAD has an approved TEMP for EMD.

TEST & EVALUATION ACTIVITY

THAAD achieved 'hit-to-kill" target intercepts in Flight Tests 10 and 11 (FT-10 and FT-11). Subsequently, the Department authorized the Army to suspend the Program Definition and Risk Reduction (PDRR) test program and enter the EMD phase. For clarity, this report provides a summary of the THAAD PDRR test program activities.

The PDRR phase of the THAAD program contained no operational testing, however, the Army and OSD Test and Evaluation (T&E) communities participated early in the planning and execution of PDRR developmental testing. A system evaluation using system and element-level PDRR data supported a key program decision to proceed to EMD.

The THAAD PDRR T&E program performed system flight testing, Hardware-In-the-Loop (HWIL) testing, element ground testing and digital simulations. Flight testing was the centerpiece of the T&E program and was conducted at White Sands Missile Range (WSMR). Successful flight tests allowed testers and developers to collect system-level data, assess the kill vehicle's seeker technology and intercept capability, and generate in-flight environmental and "end game" data. These data have led to improvements in the design of system hardware and software, and will also be used to validate models and simulations supporting system evaluations.

The program completed eleven PDRR flight tests, including eight intercept attempts. The first six of eight intercept attempts failed to achieve an intercept; the last two intercept attempts were successful.

PDRR Flight Tests

Flight Test	Date	Intercept	Discussion
FT-1	April 21, 1995	N/A	Propulsion test, no target
FT-2	July 31, 1995	N/A	Kill vehicle controls test, no target
FT-3	October 13, 1995	N/A	Target flyby test
FT-4	December 13, 1995	NO	Software error in avionics led to premature kill vehicle fuel consumption
FT-5	March 22, 1996	NO	Kill vehicle connector to booster failed at separation
FT-6	July 15, 1996	NO	Seeker electronics failure or Dewar contamination led to saturation of one half of focal plane array
FT-7	March 6, 1997	NO	Kill vehicle battery interface connection was contaminated, preventing operation of DACS thrusters
FT-8	May 12, 1998	NO	Electrical short circuit due to foreign object debris in thrust vector control caused booster failure
FT-9	March 29, 1999	NO	Attitude control system nozzle was torn from its bracket
FT-10	June 10, 1999	YES	Intercept of HERA class unitary target within aimpoint region
FT-11	August 2, 1999	YES	Intercept of HERA class separating target within aimpoint region

The Department decided to stop PDRR testing after achieving intercepts in Flight Tests 10 and 11 because significant portions of the THAAD missile will be re-designed for EMD. The early developmental tests in EMD are planned at WSMR and Kwajalein Missile Range (KMR) to prove out the new system re-design prior to committing to the production configuration. The THAAD missile re-design features between PDRR and EMD include:

- New missile mission computer.
- New cylindrical missile canister.
- Elimination of course elevation gimbal gyro.
- New Divert and Attitude Control System fuel tank with 40 percent more fuel, located aft of the divert thrusters.
- Relocation of missile avionics to accommodate center of mass change due to new Divert and Attitude Control System fuel tank.
- Changes in the Divert and Attitude Control System nozzles that increase thrust by 10 percent.
- An improved thrust vector control system on the booster.

Live Fire Test and Evaluation (Lethality). THAAD's PDRR lethality test activities included both Light Gas Gun (LGG) and high speed sled testing. THAAD lethality testing has focused on emerging targets described in the Ballistic Missile Requirements Document and specifically identified in the THAAD System Threat Assessment Report (STAR). In FY98, the Army conducted a series of eight, quarter-scale LGG tests against a heavily ballasted submunition target at the University of Alabama-Huntsville (UAH) LGG facility located on Redstone Arsenal. Those tests showed that THAAD could be lethal against that submunition target under a wide range of conditions. In FY99, another series of four LGG tests against a submunition warhead of similar design, but with a different fill, was conducted. Those tests also showed that THAAD could be lethal against the target under a wide range of conditions. Previously during FY95, the program conducted 15 dynamic sled tests at Holloman AFB, NM, against a static, threat representative target to study THAAD end game lethality. A series of ten quarter-scale LGG tests, conducted at the UAH to obtain lethality information, was completed in October 1996. These lethality tests provide the baseline for planning formal LFT&E for EMD. In 1996, DOT&E approved THAAD's live fire strategy.

In 2000, the THAAD PO and the LFT&E working group refined the approved LFT&E strategy to reflect changes to the threat, knowledge gained from testing to date, and changes to the current programmatic funding and schedule. The LFT&E strategy to be executed during EMD includes full-scale sled tests, sub-scale LGG tests, and simulation analyses using the Parametric Endo-Exoatmospheric Lethality Simulation (PEELS) model and physics-based hydrocode simulations. The evaluation will also employ lethality data from the planned EMD flight tests. The supporting EMD ground tests and analyses for LFT&E are scheduled to begin in FY02 according to the approved TEMP.

TEST & EVALUATION ASSESSMENT

The THAAD program has made significant progress by achieving two hit to kill intercepts with high accuracy. The two intercepts demonstrated limited integrated system performance among the missile, launcher, radar, and BMC^3I segments using scripted scenarios. DOT&E supported the decision to terminate testing on the PDRR missile and focus efforts on developing and testing the EMD missile design intended to improve the reliability, testability, producibility and affordability of the missile.

DOT&E's proposal for early flight testing with the new, "next-generation" missile has been integrated into the THAAD program schedule, first at WSMR--then at KMR. The early flight testing is designed to demonstrate the capability of the new missile design to reliably and accurately intercept "threat representative" ballistic missile targets. Five successful intercepts are planned prior to the Department proceeding with the second limited production buy of the new missile design. The five intercepts will also provide critical data needed to validate the missile fly-out simulation for the re-designed missile. This approach provides an incentive for the contractor and Project Manager to conduct the necessary ground testing to achieve the five intercepts with the minimum number of flight test attempts. The number of flight tests it takes to accomplish the five intercepts will provide an indication of how well the new missile design is performing so that the Department can assess the risk of continuing with the production phase of the program.

Consistent with the report of the HWIL Study Group chartered by BMDO (with DOT&E participation), the THAAD program, with strong DOT&E support, is committing to perform extensive end-to-end HWIL ground testing, including radar, missile, BMC^3I, and launcher components. End-to-end HWIL simulations should include maximum threat loading and high fidelity scene generation of the end game. Additionally, the entire system should be subjected to extreme operating environments to ensure that the system performs anywhere it is deployed.

Problems with the PDRR missile were significant. Subsequent to a THAAD Critical Technical Review in June 1997, DOT&E formally identified to BMDO a number of problem areas including design, product quality/assurance, and testing that needed to be further addressed by the prime contractor. The issues resulted in the THAAD program suspending flight testing for 14 months after FT-07, while the missile the contractor and an independent government team sponsored by the THAAD Project Manager reviewed design, pedigree, product assurance, and testing. During this timeframe DOT&E, BMDO, and DTSE&E also co-sponsored the "Welch Panel" chaired by General Larry Welch (USAF Ret.). The panel included experts from both the public and private sectors. The Welch Panel conducted a comprehensive review of all BMDO acquisition programs for obvious problem areas and deemed the following factors as most relevant to explain the inadequate performance of the THAAD PDRR system:

- The sense of urgency to deploy a UOES resulted in an overly optimistic development schedule. Rather than being event driven—proceeding in development only after technical milestones were met—the program was driven to keep pace with the planned deployment schedule. Schedule forces and budget cuts contributed to deficient manufacturing processes, quality control, product assurance, and ground testing procedures which in turn resulted in poor design, lack of quality, and failed flight tests. The ultimate result, ironically, was a schedule slip of about nine years. The Milestone III decision, initially scheduled in 1991 for FY00, is now expected no earlier than FY08.

- Quality control deficiencies in the manufacturing of the interceptor were a major factor in all but one of the flight test failures. As described above, FT-5, FT-6, FT-7, FT-8, and FT-9 failed because of some relatively low technology, manufacturing defects unrelated to the particular demands of hit-to-kill.

- The integration of high technology hit-to-kill TBM systems with common integration, assembly, test, and quality control processes has proven to be more difficult than previously anticipated. THAAD demonstrated the unique aspects of hit-to-kill technology and produced substantial amounts of in-flight environmental data during all phases of the engagement. These data, together with data collected during HWIL testing of the seeker, indicate that automated image processing performed during the end game is likely to be a major challenge in maturing this technology.

Concurrently, the Project Manager and contractor conducted a thorough examination of its practices. Actions taken to improve pre-flight testing and quality control for all subsequent flight tests included:

- Complete pedigree review of hardware design and maturity at the component and sub-system level.

- More demanding environmental stress screening and flight certification testing.

- HWIL testing of the seeker at the U.S. Army's high fidelity scene generation facility in Huntsville, AL.

At the recommendation of DOT&E, the Project Manager tested the FT-08 seeker's performance in a high fidelity HWIL facility. This represented a significant advancement in understanding the seeker capability for the THAAD program. Pre-flight testing of the seeker was conducted on all remaining PDRR seekers.

The original flight envelope for THAAD was extremely challenging since it required the THAAD missile to intercept targets flying both in the atmosphere and outside the atmosphere. As part of the missile re-design, the requirement for intercepts deep within the atmosphere is being relaxed. The required minimum engagement altitude for THAAD is still endoatmospheric but is raised higher than originally in the PDRR phase. Analyses conducted by the contractor, the PM, and the User show there is no degradation in the THAAD system against "threshold" ORD performance requirements. This means that THAAD must be fielded with a lower tier system (e.g. PAC-3) to provide the near leak-proof protection against all threats in the theater.

<u>CONCLUSIONS, RECOMMENDATIONS AND LESSONS LEARNED</u>

DOT&E's early participation in the PDRR phase of the THAAD program has directly contributed to more comprehensive pre-flight ground testing. The successes of THAAD, PATRIOT PAC-3, the Navy Area Program, and the National Missile Defense programs can be directly traced to robust pre-flight ground testing and analyses.

Stable program funding and guidance is essential for program success—especially for a program as complex as THAAD. Pressures to quickly field a TBMD capability, budget cuts, and program restructuring, combined with the freedom and flexibility allowed by acquisition reform, all strongly influenced programmatic decisions and trade-offs, with schedule as the leading priority. In the end, these decisions led to test failures and delayed the program several years.

Program execution must be event driven rather than schedule driven. Experience shows that event driven programs have the best opportunity of succeeding in the shortest time. The Welch Panel concluded that the THAAD program “rushed to failure” because the program was schedule driven.

In EMD, the THAAD contractor must implement significantly improved component-level engineering design and qualification testing, quality control processes, and product assurance testing procedures in the development and manufacturing of the interceptor. Improved component-level quality testing that confirms both design and reliability will greatly increase confidence that the “EMD” missile will perform as intended.

The THAAD program must perform thorough ground and HWIL testing of the THAAD system, including system end-to-end testing. To support the system end-to-end testing, the THAAD program must incorporate a disciplined modeling and simulation approach for verification, validation, and accreditation; and an extensive design of element and system-level model and simulation use to ensure that adequate data is generated to support integrated test and evaluation.

The THAAD PDRR missiles did not prove to be effective and reliable. Pursuing the PDRR design into EMD is not warranted given the PDRR flight test record, quality control problems, and known design problems. During the PDRR phase of development, THAAD has proven that the hit-to-kill technology and THAAD design are potentially effective against TBM missiles. Now, THAAD must revisit the design to increase its reliability, testability, producibility, and affordability.